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Climate Change and its Impact on Indian Agriculture Production

Suneel Yadav[1*] and Dr. Rekha Gupta[2]

[1-]*Assistant Professor Department of Economics SJNMPG College Lucknow, Uttar Pradesh, India.*
[2-]*Assistant Professor, Department of Economics, University of Allahabad, Prayagraj-211002, Uttar Pradesh, India.*

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Corresponding Author:
Suneel Yadav

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ABSTRACT

In the recent era the adverse impact of climate change on agriculture production has become a major concerning issue. The present study tries to assess the impact of climate change on agriculture production of wheat and rice. For the analysis secondary data has used from the various sources. Regression model has developed to capture the impact of climate change on India's agricultural production. The empirical results reveal that the impact of monsoon rainfall is positively associated with rice production and annual minimum temperature is negatively associated. Annual maximum temperature has positive association with rice production. The impact of climate factors on wheat production is found to be negative and statistically insignificant. As a result, climate change creates an adverse condition for the development of India's agriculture sector. Increasing population, economic development and urbanization consider as leading factors to increase the demand for food grains. So, there is strong need of hour to mitigate the negative impact of climate change. The net irrigated area has positive association with rice production hence development of irrigation facilities can play crucial role to reduce the negative impact of climate change on rice production

Introduction

Economic growth driven by industrialization, and economy based on fuel lead to greater emission of green-house gases (GHGs). Such strategy of growth adopted by global economy has increased the concentration of GHGs in atmosphere. This causes the earth to warm by trapping the heat which is highly concerning issue in recent time. Scientific evidence for warming of the climate system is unequivocal (IPCC, 2007). According to the World Meteorological Organisation, 2015 was warmest year, with temperature 1°C above the pre-industrial era. This was owing to El Nino and warming caused by greenhouse gases. Greater reliance on fossil fuel and coal led to unabated warming which became the cause behind the drastic change in climate. Climate was never constant but pace of change was gradual and unnoticeable. However, it gained momentum due to human activities and now it well documented that the frequency of climate related extreme events has increased. The effects of climate change are already visible in higher average air and ocean temperatures, wide spread melting of snow and ice, and rising sea levels. Cold days, cold nights, and frost have become less frequent while heat waves are more common (World Development Report, 2010). Economic cost of climate change was 1.6 percent of global GDP (1.2) trillion in 2010 which is expected to grow to 3.2 percent of global GDP in 2030 (COP-18, 2012). Studies states that climate change is adversely affecting the global output but its adverse impact on agriculture production is highly visible.

In the recent past a number of researches has attempted to assess the economic impact of climate change on agriculture production and productivity. A study by Aggrawal (2009) reports that the yields of wheat, mustard, soyabean, potato, decline by 3-7 percent due to every 1°C rises in temperature. Chatterji (1998) in their study highlighted that the agriculture is sensitive to short-term change in weather and as well seasonal, annual and long-term variations in climate. Antle (1995) has pointed out that many developing countries have large population and substantial amounts of agricultural land on or near coastlines. These areas could be threatened by inundation and intrusion of salt water into fresh water aquifers if sea levels rise. Birthal et. al (2014) have revealed that rise in temperature in kharif and rabi seasons have harmful effect on agricultural productivity. Higher rainfall, unless it is in excess has a beneficial effect but the effect is too small to offset the negative impact of temperature. Shah (2018) has presented his view that among various food-grains produced in India, rice and wheat occupy a major share, and any discernible positive or negative change in rice and wheat yields may have a significant impact on food security of the country. Guntukula et.al (2020) has find out in their study that rainfall has a significant impact on the rice yield in Telegana and maximum temperature is adversely associated with rice yield. The study also reveals that rise in maximum temperature may reduce the rice yield; however, minimum temperature has positive impact on rice yield. A review on the association between climate change and

agriculture indicates adverse impact of climate change on agriculture production and productivity which is concerning. This concern became more crucial for an economy like India, given the higher dependency of its huge population on agriculture.

India which has the second world's largest population, feeds about 17 percent of global population using only 11 percent of the world arable land. Food security is one of the long-term priorities of Indian government. The demand for food in India is increasing day by day due to population growth while arable land is decreasing due to greater industrialization, urbanization and climate change. Such tendency will make to ensure food security a difficult task in the near future. It is generally recognized that current global food production capacity is adequate to avoid famine and malnutrition, but that famine occurs because available food does not always get to those most in need (Reilly 1995). Climate change is drastically affecting the world, and India will likely be affected badly due to its population, geographical characteristics, economy and level of development. India is already witnessing the impact of climate change. According to World Bank's report (2013), the loss from natural disaster to India over the period of 1953-2009 was 150 billion rupee every year at constant prices, 2009.

The present study is an attempt to add on the trend and impact of climate change on agriculture production and productivity in the Indian context with following objectives-

- To examine the trends of climate variables that is rainfall and temperature.
- To assess the impact of climate variables on the production of rice.
- To assess the impact of climate variables on the production of wheat.

Data and Model Specification

The present study is based on the secondary data with limitation of published data availability. Data for crop-wise production, net-irrigated area, area under crop have taken from Agriculture Statistics at a glance, RBI data base. Data on variables related to climate change has workout from Indian Meteorological Department. Data on floods, cyclone, extreme events and heat waves has taken from Envi-stat 2021, Ministry of Environment Forest and Climate Change. Data on annual maximum and annual minimum temperature has used of the period from 1970 to 2014 to examine the trends. This is to get long term trends of temperature after green revolution. Rainfall trend is examined in the post reform period, 1992 to 2017.

The data of variables for regression model like rice production, wheat production, temperature, rainfall and net irrigated area has taken from period 1991 to 2017 to capture the impact of climate change on agriculture production in the post reform period as after reforms; there was greater focus on industrial sector. In the same backdrop, the present study attempt to capture the impact of climate change on agriculture production in post reform period. To establish the impact of climate variables on agriculture production, the regression model has been developed.

The regression models are -

$Yr = \beta_o + \beta 1\ MR + \beta 2\ T\ max + \beta 3\ T\ min + \beta 4\ NIA + \varepsilon i$ -1

$Yw = \beta_o + \beta 1\ WR + \beta 2\ T\ max + \beta 3\ T\ min + \beta 4\ NIA + \varepsilon i$ -2

Where, Yr and Yw are production of rice and wheat respectively. MR is monsoon rainfall and WR is winter rainfall in millimetre. T max and T min are annual maximum temperature and annual minimum temperature in celsius. NIA in net irrigated area. εi is error term; β_o is constant coefficient, β1 to β4 are coefficient of independent variables.

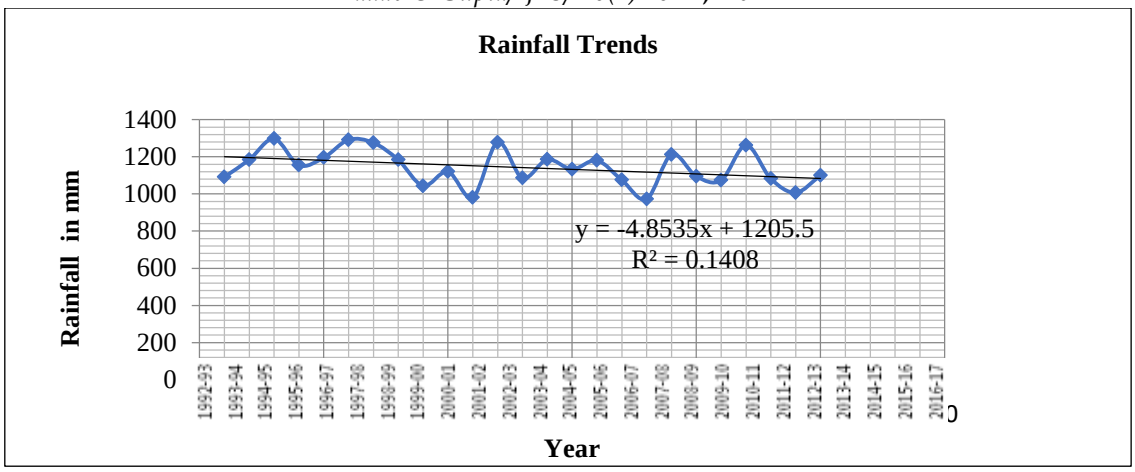
Changing Rainfall Pattern

Rainfall is crucial factor which has significant impact over the crop productivity and rain-fed crops are particularly vulnerable to the vagaries of monsoon. Rainfall patterns are already beginning to change throughout the country and further expected to change in future. The higher dependence of Indian agriculture on monsoon makes it more vulnerable. Average monsoon rainfall has declined by 26 mm between 1970 and 2016 (Hari et. al, 2018).

Figure 1.1 represents the annual rainfall (in millimetre) during 1992-1993 to 2016-17 in India. As per the figure rainfall was 1091.6 mm in 1992-93 which has increased 1212.3 mm in 2010-11 and further it has declined to 1099.4 in 2016-17. The rainfall data shows the fluctuating trends during the study period in India. Apart from this, the annual rainfall has decreased over the period of 1992-93 to 2016-17. The trends value of annual rainfall shows declining trends at magnitude of - 4.853 during the study period.

Temperature

Temperature considers as one of the key climate variables which has a significant bearing on the agriculture production. Number of global studies suggests that temperature is rising and also there is a seasonal variation in temperature. Rising and seasonal variation in temperature would increase the vulnerability of agriculture. Average annual temperature has risen by around 0.48 ℃ during the period of 1970-2016 (Hari et. al. 2018). Higher winter and summer temperatures are harmful for crops; that higher fall temperature is beneficial for crops (Mendelsohn et al).



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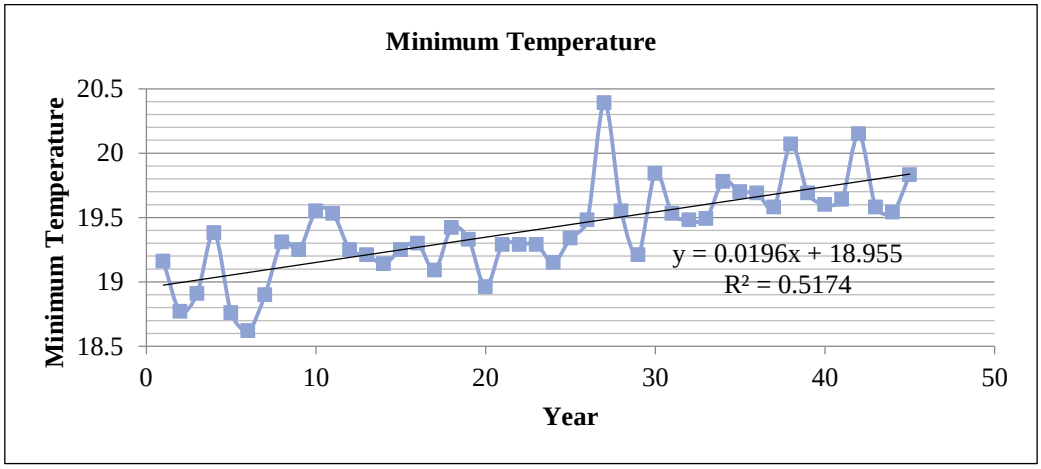
Graph 1.1 Rainfall (mm) trends for the period 1992 to 2017

Minimum Temperature

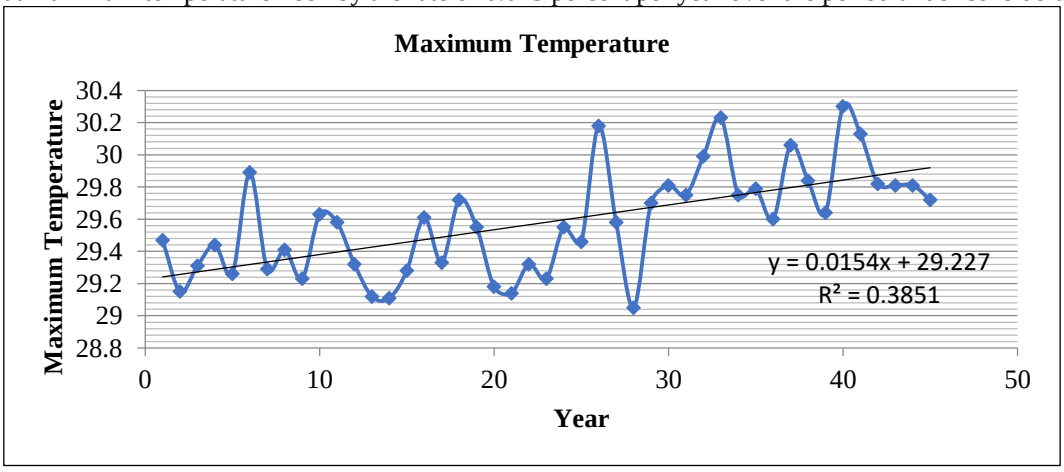
Figure 1.2 shows that there are fluctuations in minimum temperature in India during the period of 1970 -2014. Minimum temperature was 19.16 ℃ in 1970-71 and has increased to 19.77 ℃ in 2014-15. Minimum temperature has increased by 0.019 ℃ during the study period.



Graph 1.2 Annual Minimum Temperature (℃) trend for the period 1970 to 2014

Maximum Temperature

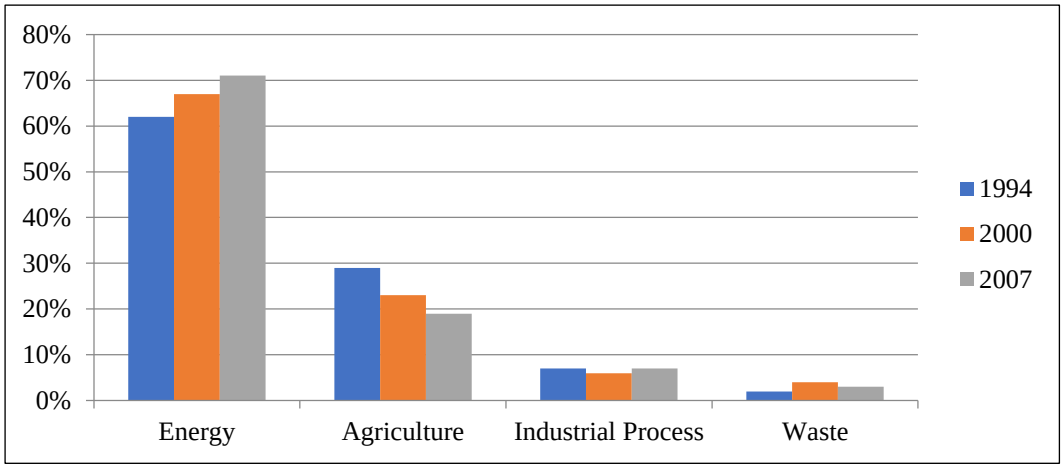
In the figure 1.3 the maximum annual temperatures in India of the period, 1970-71 to 2014-15 is plotted. Maximum temperature was 29.47 ℃ in 1970-71 which reached to 30.23 ℃ in 2001-02 and it was 29.72 ℃ in 2014-2015 in India. It could be seen from the trend line that maximum temperature risen by the rate of 0.015 percent per year over the period under consideration.



Graph 1.3: Annual Maximum Temperature (℃) trend for the period 1970 to 2014

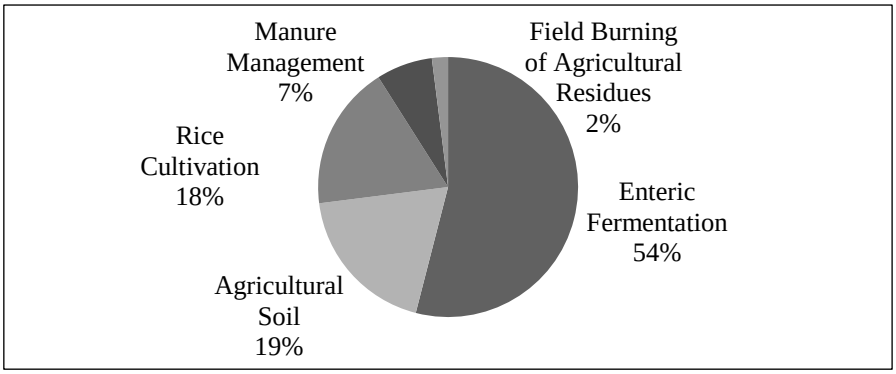
Emission of GHGs from Indian Agriculture

Agricultural activities have significant contribution in greenhouse gas emission. Intensive agriculture and more use of agro-chemicals including livestock generation in order to meet the growing food demand of increasing population have caused the exploitation of water resources. This has further aggravated the situation by release of GHGs due to agricultural activities and resulting in pollution of natural resources (Arora, 2019). Agriculture adversely affected by climate variables as well as it is also an important contributor to greenhouse gas emissions. Crop and livestock activities, together with associated land use emitted 10.4 billion tonnes of carbon dioxide of GHGs into the atmosphere in 2017 (FAOSTAT, 2020).



Graph 1.4: Emission of greenhouse gases in India from different sector. *Source- India's Biennial Update Reports*

It is observed from the chart that the emission of GHGs from agriculture sector is significant and only next to energy sector in India. Emission of GHGs from agriculture was 29 percent in 1994 of total emission in India which has come down to 19 percent in 2007. But agriculture still occupies second position in emission. The emission from agriculture is largely attributed to rice cultivation, fertilisers, stubble burning and animal husbandry.



Graph 1.5: Distribution of GHGs emissions by sub-sector from agriculture, 2014 (Gg). *Source- India's Biennial Update Reports*

As per the Pie chart, the emissions from agriculture in 2014 were mostly from enteric fermentation by the livestock including cattle, buffalo goats etc, and mostly in form of methane emission. Soil use, manure management and rice cultivation are also the culprit of emission. Stubble burning contributes to 2 percent of emission from agriculture in 2014.

Impact of Climate Change on India and its Agriculture Sector

Impacts of climate change are most likely visible. 'Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and has increased over time (IPCC 2007). Severity of impacts depends upon the vulnerability of region where climate related events are taking place. India is one the most disaster-prone country in the world. Given its long coastline, glacial Himalaya in the north and higher dependence of population on agriculture make India more vulnerable to variability of climate. 'Climate change acts as a risk multiplier for the vulnerable groups, worsening existing social, economic and environmental stresses' (Economic Survey, 2019-20).

Floods

It has observed that the flooding has increased in many agricultural regions in India over the year. Floods become very costly because it submerges the field crops, causes soil erosion, pollute water and also a very painful migration. Flood has become a constant in one region or the other in India. According to the Indian government published data, sequence of floods has affected many regions or Indian states like, Maharashtra in 2005, Andhra Pradesh and Karnataka in 2009, no one can forget the devastating flood of Uttarakhand in 2012, flood and heavy rain in Kerala and Uttar Pradesh in 2018 and many more.

Drought

Drought affects agriculture badly and its effects are more pronounced in the region where agriculture is rain-fed. 'Long term data for India indicates that rain-fed areas witness 3-4 droughts in every 10 years period. Among these, 2-3 are in moderate and one

mostly be with severe intensity' (Venkateswarlu, et al 2013). As per the Envi-stat 2021, drought affected districts in India were 80 in 2005, 338 in 2012 and 270 in 2015. Availability of water has become crucial for agriculture in recent past and if drought becomes recurring then productivity of agriculture automatically came down. Shifting towards less water requiring crop can be an option in the region where drought is frequent but it consider not safe. Shifting towards less water requiring crop in a region where drought is frequent is not free from danger as when rainfall be good then production will also come down (Kaiser et al., 1995).

Heat Waves

Rising temperature due to warming caused heat waves. Heat waves adversely are affecting human health, livestock along with agriculture. According to data published by Envi-stat -2021, the average number of heat wave days shown an increasing trend with certain fluctuations. Years 2010, 2012 and 2014 have higher number of days with average heat waves in reported states. It is remarkable to mention that there is a significant decrease in heat wave days in 2020 than that of 2019, 2018 even than that of average of 2000-2009 with exceptions of Karnataka and Maharashtra only among the reported states. It may be due to the impact of lesser carbon emission on account of lockdown.

Extreme Events and Storms

The frequency of extreme events like storms and cyclones has increased. Devastating cyclone of Orissa in 1999, Hud-Hud of Andhra Pradesh in 2015, Fani in 2019, Yass in 2021 and so on are indicators of climate change. These extreme events cause loss of life, property and livelihood.

Agriculture sector occupies a prominent position in Indian economic system. Since independence and continues to be important till date. Agricultural development is crucial for socio- economic development of Indian people. Agriculture sector is the means of livelihood for more than 60 percent population of India. 'Economic transformation of a developing country like India crucially depends on the performance of its agriculture and allied sector because this sector plays a significant role in rural livelihood, employment and food security (Economic survey, 2020-21). Agriculture supports around two-third of Indian population and it is the largest employment providing sector. Around 50 per cent of the workforce is involved in agriculture. Apart from this, it provides raw materials to various industries including cotton textiles, food processing, sugar etc. It has also significant contribution in external earnings. It is remarkable to mention that robust agricultural performance is highly positively correlated with inclusive development and poverty elimination.

Contribution of agriculture sector in the national income has gradually declined from 18.2 per cent in 2014-15 to 16.5 percent in 2019-20, reflecting the development process and structural transformation taking place in the economy (Economic survey, 2020-21). It means 16.5 per cent of GDP supports more than half of Indian population that is why people dependent on agriculture are poor and vulnerable. This reflects the importance and needs of reform in the agriculture sector.

Crop production depends on harvested areas, returns per hectare (yields) and quantities produced (FAOSTAT, 2020). It was the earlier approach to bring more land under cultivation to increase the production in India. However, most of the arable land is already under cultivation that is why strategy changed and now focus is on to increase the land productivity. It is expected that the demand for food will grow on account of growing population and changing consumption pattern. The food grains production in India is constantly growing every year and which has reached as high as 303.34 million ton in 2020-21 as per the second advance estimates. India is among the top producers of several crops such as wheat, rice pulses, sugarcane and cotton and the highest producer of milk and second largest producer of vegetables after China in the world. However, productivity is very low. India contributes 21.75 percent pulses production, 22 percent in rice and 12.32 percent in wheat. But productivity is relatively lower than China in the production of wheat and lower than China and Indonesia in rice. Moreover, in case of wheat and rice, productivity is lower than that of global average. The sector is, however, currently facing a dilemma while it has made stride in achieving the agricultural development, goals of food security, availability and accessibility. It is still being challenged by a formidable agrarian crisis' (State of Indian agriculture, 2015).

The reasons behind the sluggish performance of agriculture sector can be trace as decreasing size of land holdings, higher dependence on monsoon and lack of irrigation facilities. Apart from these, unbalanced use of fertilisers and agro-chemicals, insufficient formal credit and insurance, marketing of agro-products including climate variability are also responsible for slow or negligible growth of agriculture sector.

Results and Discussion based on Regression Model

Among many other reasons climate variables play very significant role in the production and productivity of agriculture sector. The result on the basis of model specification stated above in the data and methodology section are below. The table shows the importance of the considered variables with the various statistical tools. The result table indicates that the value of R^2 value is 0.53 which means 53 per cent variation in rice production is explained by the predictors taken in the model. F-value is significant hence model is significant that is good fit for the production of rice. The effect of monsoon rainfall (June-September) has positive and significant impact on rice production during the study period. P-value is 0.03 for monsoon rainfall which is less than 0.05 that suggests the monsoon rainfall has significant impact on rice production. Precipitation in summer has significant impact (Chen et al 2013). Kharif precipitation has significant impact (Hanif et al 2010). Minimum temperature has negative and significant impact on rice production. The optimum temperature for rice cultivation is between 25℃ and 35℃ (Ghadir Nezhad et al 2014). In this study, annual minimum temperature range is between 19.15℃ to 20.88℃. Which is not optimum for rice cultivation and this is the reason for negative and significant impact on rice production of minimum temperature. Maximum temperature has positive and insignificant impact on rice production. Impact of temperature in summer is not significant (Chen et al 2013).

Table 2.1: Result based on Regression Model 1

Dependent Variable: Rice

Independent Variables	Coefficient	t-value	p-value
Monsoon Rainfall	.141	2.341	.031
Minimum Temperature	-.142	-2.457	.022
Maximum Temperature	.104	1.513	.146
Net Irrigated Area	.946	13.925	.000
R^2	0.53		
F- value	82.024		0.004
No. Of Observations	26		

Source- Author calculation based on the data from IMD and Directorate of Economics and Statistics

Table 2.2: Result based on Regression Model 2

Dependent Variable: Wheat

Independent Variables	Coefficient	t-value	P-value
Winter Rainfall	-.101	-1.558	.135
Minimum Temperature	-.043	-.652	.522
Maximum Temperature	-.092	-1.366	.187
Net Irrigated Area	.232	1.155	.262
R^2	.48		
F- value	69.194		0.02
No. Of Observations	26		

Source- Author calculation based on the data from IMD and Directorate of Economics and Statistics

The result table shows that the value of R^2 is 0.48. It means the variation up to 48 percent in dependent variable is explained by independent variables. The F-value indicates that the model is adequate for wheat production meaning that independent variables are explaining the dependent variable significantly. The climate variables (winter rainfall, minimum temperature and maximum temperature) have negative but insignificant impact on wheat production during the study period. The P- value for winter rainfall is 0.13 which is greater than 0.05. It means the impact of winter rainfall on wheat production is negative and insignificant. Winter precipitation has not significant impact (Chen et al 2013). The p- value for annual minimum temperature is 0.52 which is much higher than 0.05. This suggests that the impact of minimum temperature is negative and insignificant on wheat production. The p-value for annual maximum temperature is 0.18 which is more than 0.05. It means the impact of annual maximum temperature on wheat production is negative and not significant. Variations in temperature have insignificant effect on wheat production (Siddiqui et. al 2012). Many of these coefficients are not significant because the climate variables are highly correlated with each other (Kurukulasuria et al 2006). Climate variables have negative but insignificant on wheat production while irrigation has positive impact suggesting that irrigation can work as a cushion against the climate variability.

Conclusion and Suggestions

To sum up, the study attempts to assess the impact of climate change on the production of rice and wheat in India with the help of secondary climate, production and planted area data. The findings of the study confirm the link between climate variables and crop production (rice and wheat). The rainfall data shows the fluctuating trends during the study period. The trends value of annual rainfall shows declining trends at magnitude of - 4.853 during the study period. On the other hand, Maximum Temperature and minimum Temperature are showing a rising trends. The study finds that monsoon rainfall is affecting rice production significantly and minimum temperature has negative and significant impact on rice production. On the hand, climate variables are negatively affecting wheat production however, impact is insignificant. Net irrigated area has positive and significant impact on rice production. It means irrigation facilities can be potent instrument for adaptation.

Adaptation refers to modification in regular practice in order to reconcile with changing climate change needs. Successful adaptation to climate change requires long-term investments research and new policy initiatives that mainstream climate change adaptation into development planning (Venkaleswarlu et.al. 2013). Adaptation measures are required to be region specific in India due to its vast size and different climate zones. Following steps can be taken-

- Improvement in technology which can reduce carbon emissions thereby less warming.
- New crop varieties can be introduced which can tolerate drought and be less water requiring.
- Step to conserve soil and steps to avoid land degradation can be undertaken like planting more trees and converting barren land into fertile land through required modification.
- Public investment in agriculture must be increased to provide irrigation facilities which have high positive correlation with crop productivity. Moreover, irrigation facilities are said be a potent weapon to deal with drought and higher temperature.
- Production of cash crop should be promoted which would lead to increase in income of farmers and also create new employment opportunities.

- To disseminate the information about climate change to the farming community so that they can undertake required steps to adapt the changing scenario.

Drought and heat tolerant seed, proper irrigation, balance use of fertilizer can mitigate the negative impact of climate variability.

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